POLYGON MIRROR, DEFLECTING APPARATUS, IMAGE FORMING APPARATUS AND METHOD OF MANUFACTURING THE POLYGON MIRROR

BACKGROUND OF THE INVENTION

This invention relates to:

(1) an image forming apparatus for a multifunctional device such as a digital copying machine, a printer and a facsimile machine or a multifunctional device having the functions thereof, or

(2) a deflecting apparatus used in a barcode reader or the like,

(3) an image forming apparatus equipped with the aforementioned deflecting apparatus, and

(4) a method for manufacturing the deflecting apparatus.

DESCRIPTION OF RELATED ART

In an image forming apparatus, a laser beam including information having been read out, is applied to a polygon mirror rotating at a high speed in a deflecting apparatus, and its reflected light is reflected onto photosensitive material by scanning, whereby an image recording is performed. A deflecting apparatus using such a polygon mirror is disclosed in many Official Gazettes of Patents. The deflecting apparatus shown in Fig. 6 is one example of such an apparatus. (See Patent Document 1, for reference).

The following describes a deflecting apparatus disclosed in Patent Document 1, with reference to Fig. 6 and Fig. 7, a perspective view where the polygon mirror is viewed from the bottom of Fig. 6:

Polygon mirror 72, equipped with reflecting surface 72a for deflecting laser beams by reflecting it onto the outer circumference surface, formed in a regular polygon is inserted into flange member 71 integrated with external cylinder bearing 73, and is bonded with the flange member 71 by means of an assembling reference surface 72b. Polygon mirror 72 is integrally held by flange member 71 and forms a mirror unit 70. In the meantime, an inner tube bearing 65 fitting with the external cylinder bearing 73 in the radial

direction, an upper thrust bearing 66 abutting the external cylinder bearing 73 in the thrust direction, and lower thrust bearing 64 are inserted into base member 60, and clamping plate 67 is clamped onto the base member 60 by machine screw 68, whereby the mirror unit 70 is positioned in the thrust direction. Further, the base member 60 is fixed with fixing yoke 61 and printed circuit board 63 provided with magnet coil 62. In the meantime, the flange member 71 is fixed with magnet 75 positioned face-to-face with magnet coil 62.

Because of the aforementioned arrangement, when power is applied to the magnet coil 62, the mirror unit 70 is rotated at a high speed with respect to the base member 60 by interaction with the magnet 77 through each bearing.

Patent Document 2 discloses a deflecting apparatus wherein a polygon mirror is pressed against a flange member by a plate spring and is fixed in a position, without bonding the polygon mirror onto the flange member.

However, when the polygon mirror is bonded to the flange material, as shown in Patent Document 1, without using a plate spring, the number of parts can be reduced and compact configuration of the deflecting apparatus can be realized with less expensive method.

Patent Document 1:

Official Gazette of Japanese Application Patent Laid-Open Publication No. 2002-48996

Patent Document 2

Official Gazette of Japanese Application Patent Laid-Open Publication No. 2002-48997

The assembling reference surface 72b of the polygon mirror 72 also serves as a processing or machining reference surface for machining the reflecting surface 72a so as to form a right angle with the assembling reference surface 72b. Therefore, the assembling reference surface 72b is finished to a surface roughness similar to that of a mirror finish (0.06 μm or less in terms of arithmetic mean roughness Ra specified in the JIS B0601 or ISO 468-1982). The holding surface 71a of the flange member 71 for holding the polygon mirror 72 is also finished to a high accuracy with a right angle to the rotary axis of the external cylinder bearing 73. As described above, the assembling reference surface 72b of the polygon mirror 72 is butted and adhered to the holding surface 71a of the flange member 71.

In the meantime, when the deflecting apparatus is used, the polygon mirror 72 rotates at a high speed; therefore, the temperature of the deflecting apparatus rises to 60 through

70 °C, and then gets back to normal temperature when it is not used. Since such a temperature change occurs and there is a difference in the shrinkage rate between a polygon mirror 72 and a flange member 71, there may be separation of adhesion between assembling reference surface 72b of polygon mirror 72 and holding surface 71a of flange member 71.

In view of prior art described above, present invention has been made. An objective of this invention is to provide a polygon mirror, a deflecting apparatus, an image forming apparatus, and a polygon mirror manufacturing method, wherein aforementioned polygon mirror is characterized by a high degree of reliability; when a polygon mirror is adhered to a flange member, they are not easily separated when exposed to a change in temperature etc, and stable optical characteristics (tilt angle of the reflected surface) of the polygon can be guaranteed.

SUMMARY OF THE INVENTION

The aforementioned objective can be achieved by any of the following means:

(1) A polygon mirror, formed in a regular polygon and having a reflecting surface on each circumference surface, comprising:

a machining reference surface having been planished to serve as a reference surface for working the reflected surface; and

an assembling reference surface arranged parallel to the aforementioned machining reference surface and subjected to roughened surface to serve as a reference surface for polygon assembling.

(2) A deflecting apparatus comprising:

a base member;

a polygon mirror formed in a regular polygon and having a reflecting surface on each circumference surface; and

a flange member for holding the aforementioned polygon and rotating with respect to the aforementioned base member;

wherein the polygon mirror further contains a machining reference surface, planished to serve as a machining reference surface for planishing the reflecting surface, and an assembling reference surface arranged parallel to the aforementioned machining reference surface and subjected to a roughed surface to serve as a reference surface for polygon assembling; and the assembling reference surface is butted and bonded to the flange member.

(3) An image forming apparatus comprising a deflecting apparatus described in (2).

(4) A method for producing a polygon mirror comprising the steps of

means for fixing a first end surface of roughly processed polygon mirror material shaped in polygon, onto a processing machine;

means for forming a machining reference surface by planishing a second end surface located in back side of the first end surface;

means for forming an assembling reference surface for assembly of polygon mirror by roughly finishing a surface different from the second end surface in parallel with the machining reference surface and being dented in the direction of the rotation axis of the polygon mirror;

means for planishing the first end surface so that the first end surface is parallel with the machining reference surface by fixing the machining reference surface onto machine; and

means for planishing each circumferential surface of the reflection surface by stacking a plural of material processed in the steps above, along rotational axis direction of the polygon mirror.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a perspective view representing a beam scanning optical apparatus equipped with a deflecting apparatus;

Fig. 2 is a vertical sectional view representing a deflecting apparatus;

Fig. 3 is a sectional view of a polygon mirror;

Fig. 4 is a perspective view representing the polygon mirror as viewed from the bottom;

Fig. 5 is a vertical cross sectional view of the deflecting apparatus, with an enlarged view;

Fig. 6 is a vertical cross sectional view of a prior art deflecting apparatus; and

Fig. 7 is a perspective view representing the prior art polygon mirror as viewed from the bottom.

DETAIL DESCRIPTION OF THE INVENTION

The following describes an embodiment of a beam scanning optical apparatus having a deflecting apparatus with reference to Fig. 1:

In Fig. 1, numeral 1 denotes a deflecting apparatus equipped with a polygon mirror 1a, 2, a semiconductor laser, 3 a collimator lens for beam shaping optical system, 4, a

first cylindrical lens, 5 and 6, fθ lenses, 7, a second cylindrical lens, 8, a mirror, 9, a cover glass, and 10, a photosensitive material drum. Numeral 11, shows an index mirror for synchronization detection, and 12, an index sensor for synchronization detection.

Laser beams emitted from semiconductor laser 2 is converted into parallel beams by collimator lens 3, passed through a first cylindrical lens 4 of a first image formation optical system and guided to a reflecting surface of polygon mirror 1a which rotates at a constant high-speed in deflecting apparatus 1. Laser beams reflected by the reflecting surface of polygon mirror 1a pass through a second image formation optical system comprising fθ lenses 5 and 6 and second cylindrical lens 7, and main scanning is carried out with a pre-determined laser beam spot size on the circumference surface of photosensitive material drum 10. Direction of main scanning is finely adjusted by an adjusting mechanism (not illustrated), and synchronization detection for each line is performed prior to starting of scanning by guiding the laser beams into index sensor 12 through index mirror 11.

To get a satisfactory latent image on photosensitive material drum 10, such a beam scanning optical apparatus is required to ensure that polygon mirror 1a is formed in a regular polygon, a plurality of high-precision reflecting surfaces are provided, and high-speed rotation is enabled without any tilt with respect to axis of rotation and displacement with respect to rotation axis of photosensitive material drum 10.

The following describes a deflecting apparatus mounted on the aforementioned beam scanning optical apparatus and the polygon mirror with reference to Figs. 2 through 4: Fig. 2 is a vertical sectional view representing a deflecting apparatus. Fig. 3 is a sectional view of a polygon mirror, and Fig. 4 is a perspective view representing the polygon mirror as viewed from the bottom.

In Fig. 2, numeral 20 denotes a base member, which is made of a metal such as aluminum. It holds various members to be described later, and is secured on the aforementioned beam scanning optical apparatus. A fixing yoke 21 is secured on the upper surface of the base member 20. A printed circuit board 23 with a plurality of magnetic coils 22 mounted thereon is also secured in position.

Holding surface 31c for holding polygon mirror 32 is arranged on the top surface of flange 31a. External cylinder bearing 33 is inserted integrally into a hole provided at the center of the cylindrical portion 31b in flange member 31 by shrinkage fitting or inserting under pressure.

The flange member 31 and bearing 33 may be formed integrally with each other.

The polygon mirror 32 is formed in a high-precision regular polygon by metal such as aluminum, and is provided with reflecting surface 32a for reflecting and deflecting laser beams on an outer circumference surface of polygon mirror 32. This polygon mirror 32 is inserted into the outer peripheral portion of the cylindrical portion 31b in the flange member 31, and assembling reference surface 32b of the polygon mirror 32 is butted on the holding surface 31c and is adhered by adhesive agent 40. The holding surface 31c of the flange member 31 is perpendicular to a rotation axis of and is finished with mirror surface quality. As will be described later, the assembling reference surface 32b of the polygon mirror 32 is subjected to a roughened surface; therefore, the adhesive agent 40 spreads into the recesses of the rough surface. The assembling reference surface 32b is firmly secured on the holding surface 31c. Therefore, even

if there is a change in temperature, the polygon mirror 32 is not easily separated from the flange member 31.

As will be described later, the polygon mirror 32 has machining reference surface 32d as a reference for working reflecting surface 32a, separately from assembling reference surface 32b as a reference for assembling. Since the machining reference surface 32d and assembling reference surface 32b are formed in parallel to each other, the tilt angle of the reflecting surface 32a can be maintained at an appropriate level when the polygon mirror 32 is bonded to the flange member 31.

Permanent magnet 34 located opposite to magnet coil 22, for generating rotary torque, is bonded on the bottom of the flange member 31 by adhesive agent.

As described above, mirror unit 30 is comprised of flange member 31, polygon mirror 32 external cylinder bearing 33 and permanent magnet 34.

A shaft 20a is arranged upright at the center of base member 20. A lower thrust bearing 24 is fitted to shaft 20a, and internal cylindrical bearing 25 is also fitted therein. This is followed by the step of fitting external cylinder bearing 33 of mirror unit 30 into internal cylindrical bearing 25. An upper thrust bearing 26 is fitted to the

shaft 20a and is secured by screwing machine screw 27 into shaft 20a. The internal cylindrical bearing 25, external cylinder bearing 33, lower thrust bearing 24 and upper thrust bearing 26 are composed of alumina and ceramics such as silicon nitride.

As described above, in the external cylinder bearing 33 holding the mirror unit 30, the radial bearing is formed by the internal cylindrical bearing 25, and radial dynamic rotation is performed. A thrust bearing is constituted by the lower thrust bearing 24 and upper thrust bearing 26, whereby thrust dynamic rotation is formed. Dynamic pressure generating groove is formed with at least one of the bearing surface of the lower thrust bearing 24, bearing surface of the upper thrust bearing 26 or the outer circumference surface of the internal cylindrical bearing 25. Thus, wind produced by high-speed rotation enters the dynamic pressure generating groove, and a gap of about 3 through 10 μm is produced between each of the fixed bearings and the external cylinder bearing 33 by heavy wind pressure generated from the dynamic pressure generating groove, with the results that resistance between them will be reduced. Thus, the mirror unit 30 comes to a non-contact state, resulting in a smooth and high-speed rotation.

In the manner described above, the deflecting apparatus is formed. Since the mirror unit 30 makes a high-speed rotation, there will be a wind noise offensive to the ears due to disturbance of airflow or noise due to vibration. Especially in the office where quiet atmosphere is required, noise preventive measures must be taken. To solve this problem, it is preferred to provide a cover opposite to the base member 20, thereby protecting the mirror unit 30 or the like.

It is also possible to provide a cover disclosed in the Official Gazette of Japanese Patent Laid-Open No. 1999-84296. To ensure firm bonding of the polygon mirror to the flange member, the polygon mirror can be formed as shown in Fig. 5. Fig. 5(a) is a vertical cross sectional view of the same deflecting apparatus as that of Fig. 2. Fig. 5(b) is an enlarged view of the section A given in Fig. 5(a).

In the polygon mirror 52 of Fig. 5, ring-shaped slits 52e and 52f are formed along the outer and inner circumference of assembling reference surface 52b. Therefore, the adhesive agent 40 for bonding the holding surface 31c between the assembling reference surface 52b and flange member 31 spreads into the slits 52e and 52f, with the

result that the flange member 31 is firmly held in position by the polygon mirror 52.

The slits 52e and 52f need not always be formed along both the outer and inner circumference of the assembling reference surface 52b. It can be formed along either the outer or inner circumference.

The following describes the method of producing polygon mirror 32 with reference to Figs. 3 and 4:

(1) A first end surface 32c of polygon mirror material formed on a regular polygon is mounted on the polygon mirror-working machine.

(2) A second end surface located on the back of the first end surface 32c is planished by cutting operation and is formed into a machining reference surface 32d.

(3) A surface different from the machining reference surface 32d on the second end surface is formed by a polycrystalline diamond cutting tool in such a way that it will be in parallel with the machining reference surface 32d, and will be dented by several tens of micron meters with respect to the machining reference surface 32d in the direction of the rotation axis, thereby forming a assembling reference surface 32b so that the surface roughness will be

0.16 μm or more, but not more than 21.8 μm in terms of arithmetic mean roughness Ra.

The aforementioned arithmetic mean roughness Ra is specified in the JIS B0601 or ISO 468-1982.

(4) The material having been worked in the aforementioned steps is removed from the machine and the machining reference surface 32d is mounted on the machine, contrary to the aforementioned description. The first end surface 32c is planished so that it will be parallel to the machining reference surface 32d.

(5) A plurality of materials machined in the above steps are loaded, and the reflecting surface 32a on each circumference surface is planished so that it will be perpendicular to machining reference surface 32d, whereby the production of the polygon mirror 32 is completed.

In the aforementioned working procedures, the machining reference surface 32d and assembling reference surface 32b are positioned to the second end surface on the same side. They can be positioned to different end surfaces.

In the above step, machining operations are made in such a way that the surface roughness of the assembling reference surface 32b will be 0.16 μm or more, but not more than 21.8 μm in terms of arithmetic mean roughness Ra. The

reason for this step will be described with reference to Table 1.

Table 1

Surface roughness of working reference surface (μm)	Polygon mirror separation strength (N)	
	Before heat shock test	After heat shock test
0.09	4.16	2.21
0.16	4.31	3.83
0.62	4.03	3.72
1.21	4.34	3.91
5.35	4.07	4.19
12.2	4.24	3.97
21.8	3.95	3.91
25.1	3.31	2.67

The surface roughness of assembling reference surface 32b was changed according to a cutting tool feed rate, the amount of in-feed and the speed of the lathe to produce ten polygon mirrors 32 having different surface roughness. The THREE BOND 2204 (R) as a one-part epoxy adhesive was used to bond the assembling reference surface 32b to the holding surface 31c of the flange member 31. This was followed by the step of heat shock tests (50 cycles, at -30 through +75 degrees Celsius maintained for one hour). Then the separation strength of polygon mirror 32 (N) was measured before and after the heat shock test.

The aforementioned has revealed that, when the surface roughness of assembling reference surface 32b is 0.09 μm in terms of arithmetic mean roughness Ra, the separation strength after heat shock test exhibits a substantial reduction. When the surface roughness of the assembling reference surface 32b is 25.1 μm in terms of arithmetic mean roughness Ra, the separation strength before and after heat shock test is small. It is estimated that this excessive surface roughness causes bubbles to enter the bonded surface. Thus, the best separation strength is ensured when the surface roughness of the assembling reference surface 32b will be 0.16 μm or more, but not more than 21.8 μm, preferably 0.2 μm or more, but not more than 20 μm in terms of arithmetic mean roughness Ra.

In a polygon mirror, a deflecting apparatus, an image forming apparatus and a polygon mirror manufacturing method of the present invention, the polygon mirror has a machining reference surface as a reference for working the reflecting surface, apart from the assembling reference surface as a reference for assembling, so that they are parallel to each other. The machining reference surface is planished and the assembling reference surface is subjected to surface roughing. Thus, the reflecting surface is processed to a

high precision, and when the polygon mirror is bonded with the flange member in order to assemble the polygon mirror, the adhesive is allowed to spread into the dents of the rough surface on the polygon mirror assembled reference surface; therefore, the assembled reference surface is firmly secured on the holding surface of the flange member. Thus, the polygon mirror and flange member is not easily disconnected when there is a change in temperature. The advantage of this effect of the present invention is further promoted by the high reliability where stable optical characteristics (tilt angle of the reflected surface) of the polygon are ensured.